

**What is claimed is:**

1. A single-mode optical fiber suitable for a WDM (Wavelength Division Multiplexing) system, comprising:
  - 5 (a) a first core region positioned in the center of cross section and having a radius  $r_1$  from the center and a relative refractive index difference  $\Delta_1$ ;
  - (b) a second core region surrounding the first core region and having a radius  $r_2$  from the center and a relative refractive index difference  $\Delta_2$ ;
  - (c) a third core region surrounding the second core region and having a radius  $r_3$  from the center and a relative refractive index difference  $\Delta_3$ ; and
  - 10 (d) a clad region surrounding the third core region and having a radius  $r_4$  from the center and a relative refractive index difference  $\Delta_4$ ,
  - (e) wherein the radii of the regions have a relation of  $r_1 < r_2 < r_3 < r_4$ , and the relative refractive index differences of the regions have relations of  $\Delta_1 > \Delta_2$ , and
  - 15  $\Delta_2 < \Delta_3$ ;
  - (here,  $\Delta_1(\%) = [(n_1 - n_c)/n_c] \times 100$ ,  $\Delta_2(\%) = [(n_2 - n_c)/n_c] \times 100$ ,  $\Delta_3(\%) = [(n_3 - n_c)/n_c] \times 100$ ,  $n_1$ : a reflective index of the first core region,  $n_2$ : a reflective index of the second core region,  $n_3$ : a reflective index of the third core region,  $n_c$ : a reflective index of the clad region)
  - 20 (f) wherein the optical fiber uses a wavelength region from 1460 to 1625 nm, and has a dispersion value of 0.1 to 3.0 ps/nm-km at 1460 nm, 3.0 to 5.5 ps/nm-km at 1550 nm, and 4.5 to 8.0 ps/nm-km at 1625 nm.

2. The single-mode optical fiber according to claim 1,  
wherein the optical fiber has a positive dispersion slope in the wavelength band  
for use.
- 5 3. The single-mode optical fiber according to claim 2,  
wherein the optical fiber has a dispersion slope of 0.023 to 0.05 ps/nm-km<sup>2</sup> at  
1550 nm.
- 10 4. The single-mode optical fiber according to claim 3,  
wherein the optical fiber has an effective section area of 35 to 50μm<sup>2</sup> at 1550  
nm.
- 15 5. The single-mode optical fiber according to claim 3,  
wherein the optical fiber has an effective section area of 35 to 50μm<sup>2</sup> at 1460  
nm.
6. The single-mode optical fiber according to claim 4 or 5,  
wherein the optical fiber has a cutoff wavelength of 1450 nm or below.
- 20 7. The single-mode optical fiber according to claim 4 or 5,  
wherein a zero-dispersion wavelength is located at 1460 nm or below.
8. The single-mode optical fiber according to claim 4 or 5,

wherein the optical fiber has a dispersion value of 0.3 to 2.4 ps/nm-km at 1460 nm.

9. The single-mode optical fiber according to claim 4 or 5,  
5 wherein the optical fiber has a dispersion value of 3.2 to 5.2 ps/nm-km at 1550 nm.

10. The single-mode optical fiber according to claim 4 or 5  
wherein the optical fiber has a dispersion value of 4.8 to 7.7 ps/nm-km at 1625  
10 nm.

11. The single-mode optical fiber according to claim 10,  
wherein a bending loss is 0.5dB or less at 1625 nm under the condition of a  
bending radius of 30mm, 100turns.

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12. The single-mode optical fiber according to claim 1,  
i) wherein the first core region has a radius  $r_1=3.05\pm0.6\mu\text{m}$  and a relative  
refractive index difference  $\Delta_1(\%)=0.54\pm0.03\%$ ;  
ii) wherein the second core region has a radius  $r_2=5.38\pm0.6\mu\text{m}$  and a refractive  
20 index difference  $\Delta_2=-0.20\pm0.03\%$ ; and  
iii) wherein the third core region has a radius  $r_3=9.96\pm0.6\mu\text{m}$  and a specific  
refractive index difference  $\Delta_3=0.07\pm0.03\%$ .

13. The single-mode optical fiber according to claim 1,

i) wherein the first core region has a radius  $r_1=3.05\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_1(\%)=0.55\pm0.03\%$ ;

5 ii) wherein the second core region has a radius  $r_2=5.75\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_2=-0.18\pm0.03\%$ ; and

iii) wherein the third core region has a radius  $r_3=10.79\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_3=0.09\pm0.03\%$ .

14. The single-mode optical fiber according to claim 1,

10 i) wherein the first core region has a radius  $r_1=3.12\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_1(\%)=0.53\pm0.03\%$ ;

ii) wherein the second core region has a radius  $r_2=5.56\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_2=-0.23\pm0.03\%$ ; and

15 iii) wherein the third core region has a radius  $r_3=9.92\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_3=0.10\pm0.03\%$ .

15. The single-mode optical fiber according to claim 1,

i) wherein the first core region has a radius  $r_1=3.24\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_1(\%)=0.48\pm0.03\%$ ;

20 ii) wherein the second core region has a radius  $r_2=5.72\pm0.6\mu\text{m}$  and a relative refractive index difference  $\Delta_2=-0.17\pm0.03\%$ ; and

iii) wherein the third core region has a radius  $r_3=8.54\pm0.6\mu\text{m}$  and a relative

refractive index difference  $\Delta_3 = 0.15 \pm 0.03\%$ .

16. The single-mode optical fiber according to claim 1,

5 i) wherein the first core region has a radius  $r_1 = 3.37 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_1(\%) = 0.50 \pm 0.03\%$ ;

ii) wherein the second core region has a radius  $r_2 = 5.77 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_2 = -0.25 \pm 0.03\%$ ; and

iii) wherein the third core region has a radius  $r_3 = 9.35 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_3 = 0.14 \pm 0.03\%$ .

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17. The single-mode optical fiber according to claim 1,

i) wherein the first core region has a radius  $r_1 = 3.18 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_1(\%) = 0.51 \pm 0.03\%$ ;

15 ii) wherein the second core region has a radius  $r_2 = 6.18 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_2 = -0.19 \pm 0.03\%$ ; and

iii) wherein the third core region has a radius  $r_3 = 8.65 \pm 0.6 \mu\text{m}$  and a relative refractive index difference  $\Delta_3 = 0.14 \pm 0.03\%$ .

18. A single-mode optical fiber suitable for a WDM (Wavelength Division  
20 Multiplexing) system, comprising:

(a) a first core region positioned in the center of cross section and having a radius  $r_1$  from the center and a relative refractive index difference  $\Delta_1$ ;

(b) a second core region surrounding the first core region and having a radius  $r_2$  from the center and a relative refractive index difference  $\Delta_2$ ;

(c) a third core region surrounding the second core region and having a radius  $r_3$  from the center and a relative refractive index difference  $\Delta_3$ ; and

5 (d) a clad region surrounding the third core region and having a radius  $r_4$  from the center and a relative refractive index difference  $\Delta_4$ ,

(e) wherein the radii of the regions have a relation of  $r_1 < r_2 < r_3 < r_4$ , and the relative refractive index differences of the regions have relations of  $\Delta_1 > \Delta_2$ , and  $\Delta_2 < \Delta_3$ ;

10 (here,  $\Delta_1(\%) = [(n_1 - n_c)/n_c] \times 100$ ,  $\Delta_2(\%) = [(n_2 - n_c)/n_c] \times 100$ ,  $\Delta_3(\%) = [(n_3 - n_c)/n_c] \times 100$ ,  $n_1$ : a reflective index of the first core region,  $n_2$ : a reflective index of the second core region,  $n_3$ : a reflective index of the third core region,  $n_c$ : a reflective index of the clad region)

(f) wherein the optical fiber uses wavelength region from 1460 to 1625 nm, and  
15 has a dispersion value of 0.1 to 3.0 ps/nm-km at 1460 nm, 3.0 to 5.5 ps/nm-km at 1550 nm, and 4.5 to 8.0 ps/nm-km at 1625 nm;

(g) wherein a dispersion slope at 1550 nm is 0.023 to 0.05 ps/nm-km<sup>2</sup>;

(h) wherein an effective section area at 1550 nm is 35 to 50  $\mu\text{m}^2$ .

20 19. The single-mode optical fiber according to claim 18,  
wherein the optical fiber has an effective section area of 35 to 50  $\mu\text{m}^2$  at 1460 nm.

20. The single-mode optical fiber according to claim 18,  
wherein the optical fiber has a cutoff wavelength of 1450 nm or below.

5 21. The single-mode optical fiber according to claim 18,  
wherein a zero-dispersion wavelength is located at 1460 nm or below.

22. The single-mode optical fiber according to claim 18,  
wherein the optical fiber has a dispersion value of 0.3 to 2.4 ps/nm-km at 1460  
nm.

10 23. The single-mode optical fiber according to claim 18,  
wherein the optical fiber has a dispersion value of 3.2 to 5.2 ps/nm-km at 1550  
nm.

15 24. The single-mode optical fiber according to claim 18,  
wherein the optical fiber has a dispersion value of 4.8 to 7.7 ps/nm-km at 1625  
nm.

20 25. The single-mode optical fiber according to claim 18,  
wherein a bending loss is 0.5dB or less at 1625 nm under the condition of a  
bending radius of 30mm, 100turns.

26. An optical transmission line in which the single-mode optical fiber

defined in any of claims 1 to 18 is adopted.

27. An optical transmission system in which the optical transmission line defined in claim 26 is adopted in at least a part of an optical transmission path.

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